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STATUS OF GEOSYNCHRONOUS PLASMA MODELING

H. B. GARRETT

(Presented by J. M. RATLIFF)

STATUS OF GEOSYNCHRONOUS PLASMA MODELING

- **AGENDA**
  - Overview of plasma environment studies
  - Spacecraft data bases for geosynchronous plasma study
  - Statistical modeling
  - Analytical modeling
  - Current status of activities

OVERVIEW OF PLASMA ENVIRONMENT STUDIES

- **Reviewed 0-100 KeV Earth plasma environments:**
  - **Garrett, H. B., "Review of Quantitative Models of the 0 to 100 KeV Near Earth Plasma", Rev. Geophys., 17, 397-417, 1979**
- **Developed atlases of ATS-5, ATS-6, and SCATHA plasma measurements:**
  - **Garrett, H. B., "Modeling of the Geosynchronous Orbit Plasma Environment-Part I", AFGL-TR-77-0288, 1978.**
  - **Garrett, H. B., Mullen, E. G., Ziemba, E., Deforest, S. E., "Modeling of the Geosynchronous Plasma Environment-Part 2. ATS-5 and ATS-6 Statistical Atlas", AFGL-TR-78-0304, 1978.**
  - **Garrett, H. B., McInerney, R. E., Deforest, S. E., Johnson, B., "Modeling of the Geosynchronous Orbit Plasma Environment-Part 3, ATS-5 and ATS-6 Pictorial Data Atlas", AFGL-TR-79- 0015, 1979.**
  - **Mullen, E. G., Garrett, H. B., Hardy, D. A., Whipple, E. C., "P78-2 SCATHA Preliminary Data Atlas", AFGL-TR-80-0141, 1980.**
- **Compared with other spacecraft to develop in-situ monitoring system**
  - **Garrett, H. B., Schwank, D. C., Higbie, P. R., Baker, D. N., "Comparison Between the 30-80 KeV Electron Channels on ATS-6 and 1976-059A During Conjunction and Application to Spacecraft Charging Prediction", J. Geophys. Res., 85, 1155-1162, 1980.**

OVERVIEW OF PLASMA ENVIRONMENT STUDIES

- **Near Earth plasma environment divided into 4 regimes:**
  - **Plasmasphere**
  - **Plasma Sheet**
  - **Polar Regime**
  - **Van Allen Belts**
- **Models grouped in terms of:**
  - **Statistical: Averages, Standard Deviations, Scatter Plots, etc. of Key Parameter**
  - **Analytic: Representations of Parameters in terms of Local Time, Geomagnetic Activity, L-Shell, etc.**
  - **Static: Physics-Based Models for Static Magnetic and Electric Fields**
  - **Time-Dependent: Full, Time Varying Magnetic and Electric Fields with Time-Dependent Sources and Sinks**
- **Garrett and colleagues' studies have concentrated on plasma sheet :**
  - **Primarily Geosynchronous Region Though SCATHA Monitored Other L-shells and Statistical Auroral Models Were Also Developed**
  - **Limited to Statistical and Analytic Models**

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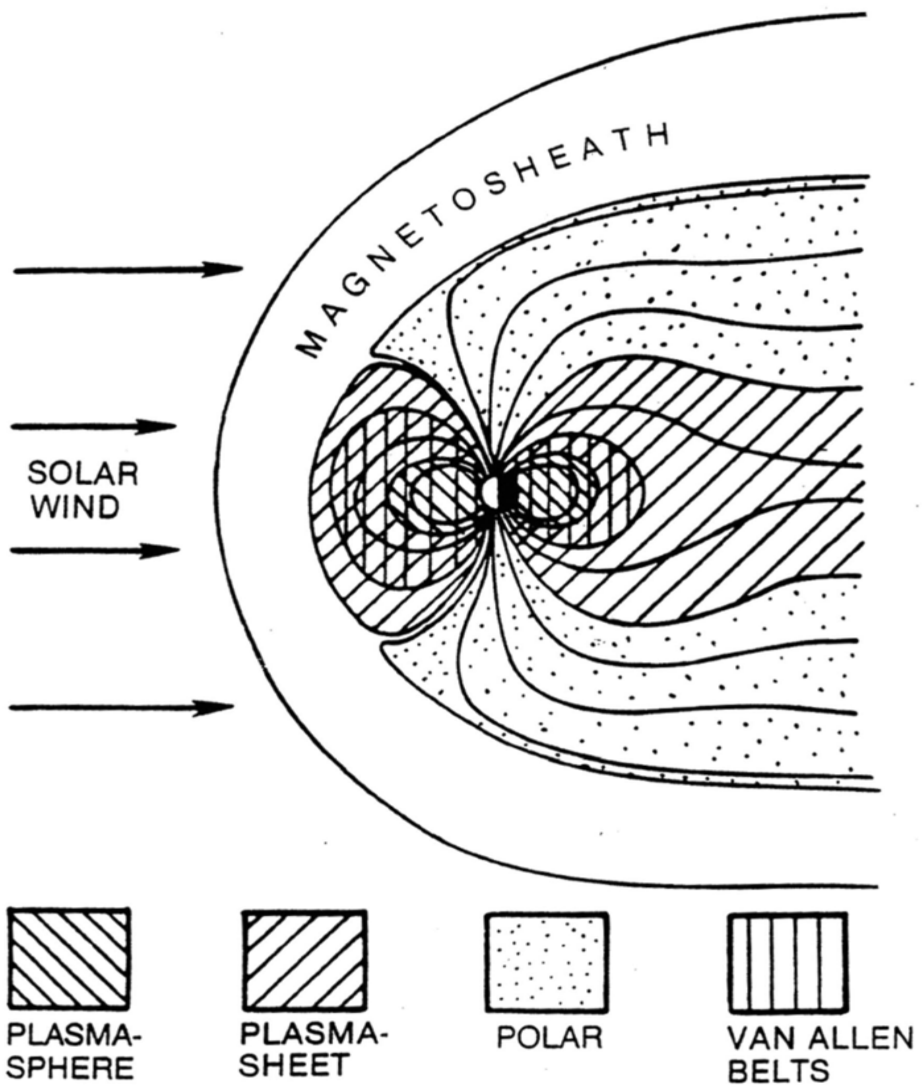
THE EARTH'S MAGNETOSPHERIC REGIONS



EXAMPLE OF STATISTICAL STUDIES

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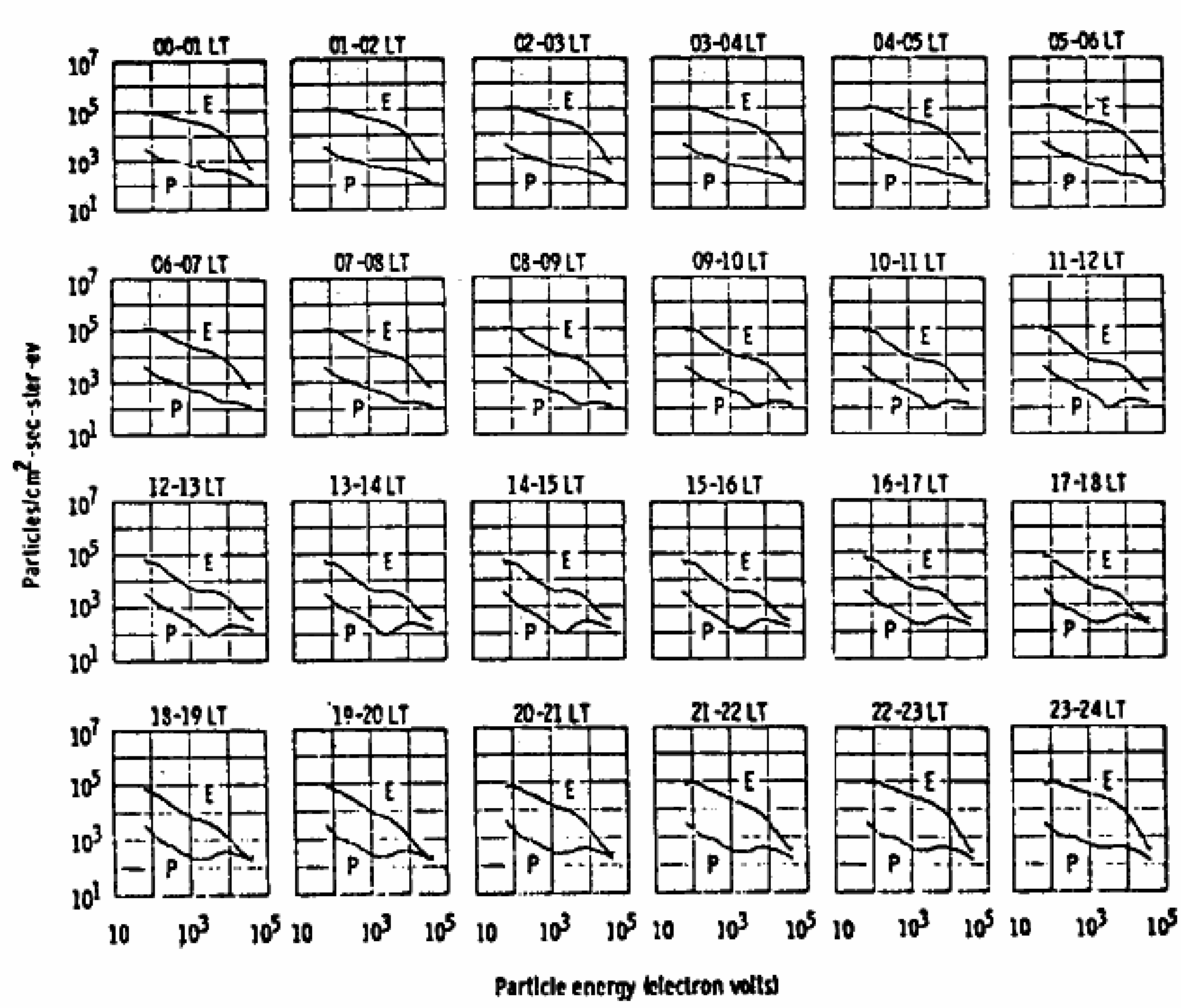

ATS-5 GEOSYNCH ENERGY SPECTRA AVERAGED IN LOCAL TIME (SU AND KONRADI, 1977)

EXAMPLE OF TIME-DEPENDENT PLASMA MODEL

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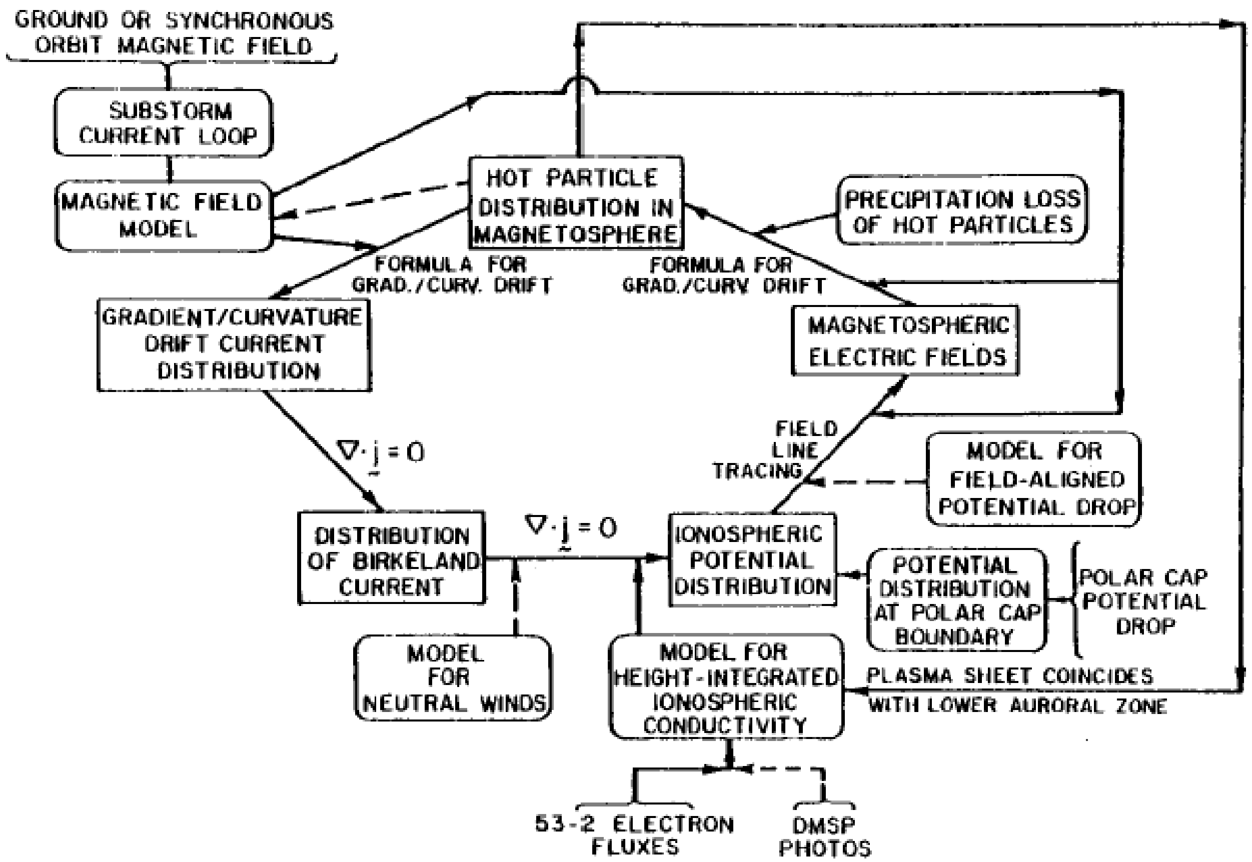

RICE UNIVERSITY MAGNETOSPHERIC MODEL (WOLF ET AL.)

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SPACECRAFT DATA BASES FOR GEOSYNCHRONOUS PLASMA STUDIES

– ATS-5 UCSD Low Energy Plasma Detectors:

- 62 energy channels (e^-,I^+)
- Spectra every 20s in 112% steps—51 eV to 51 KeV
- Spacecraft at ~225°E
- 10 minute bins for 50 day; 1969-1970

– ATS-6 UCSD Low Energy Plasma Detectors:

- 62 energy channels (e^-,I^+)
- Spectra every 15s in 113% steps—1 eV to 81 KeV
- Spacecraft at ~266°E
- 10 minute bins for 45 days; 1974-1976; 10 days Sept 14-25, 1976 (CPA Study)

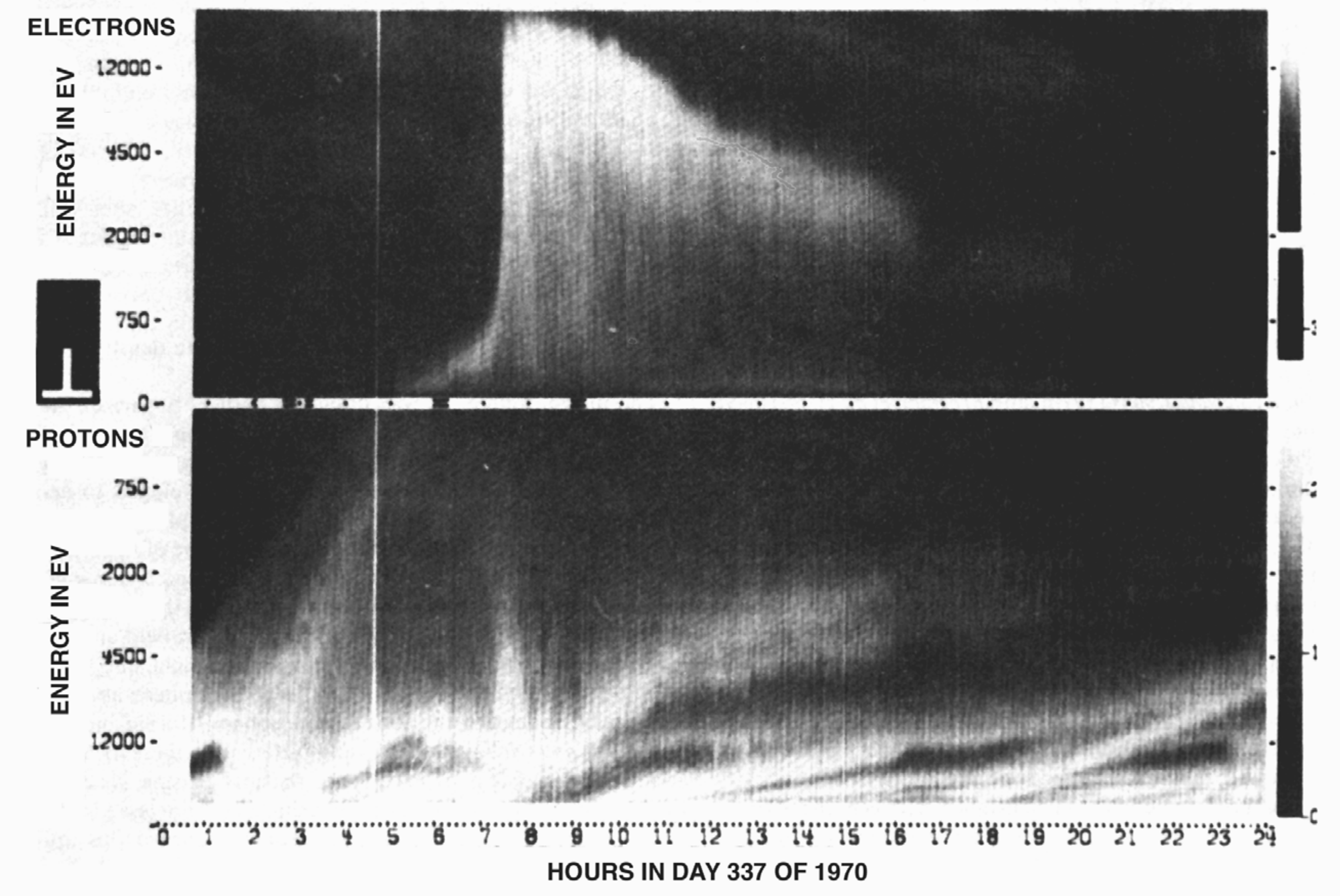
– SCATHA (5.5 R_e-7.7 R_e):

- AFGL SC5 Rapid Scan Particle Detector (e^-,I^+)
  1 s, 50 eV to 0.5 MeV
- UCSD SC9 (~ATS-6) (e^-,I^+)
  .25 s 1 eV to 81 KeV

– 1976-059A (LANL CPA)

- 30-, 44-, 64.5-, 95-300 KeV electrons
- 10 minute averages for 10 days (Sept 14-25, 1976)

ATS-5 SPECTROGRAM



STATISTICAL MODELING

- **Basic data set(s) were 10 minute average electron and ion spectra**
- **Data were integrated in energy to give first 4 moments of plasma distribution function**
- **4 moments correspond mathematically to to "2 Maxwellian" fit**
- **Moments and 2 Maxwellian fit parameters statistically analyzed (Averages, Standard Deviations, Cross-Correlation Plots, etc.)**

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PLASMA DISTRIBUTION FUNCTION

THE MAXWELL-BOLTZMANN PLASMA DISTRIBUTION FUNCTION

$$F(v) = n\left(\frac{m}{2\pi KT}\right)^{3/2} e^{\left(\frac{-mv^2}{2KT}\right)}$$

MOMENTS OF THE PLASMA DISTRIBUTION FUNCTION

NUMBER DENSITY:

$$\langle ND \rangle = 4\pi \int_o^\infty \left(v^0\right) F v^2 dv = n$$

NUMBER FLUX:

$$\langle NF \rangle = \int_o^\infty \left(v^1\right) F v^2 dv = \left(\frac{n}{2\pi}\right)\left(\frac{2KT}{\pi m}\right)^{1/2}$$

ENERGY DENSITY:

$$\langle ED \rangle = \frac{4\pi m}{2} \int_o^\infty \left(v^2\right) F v^2 dv = \frac{3}{2} nKT$$

ENERGY FLUX:

$$\langle EF \rangle = \frac{m}{2} \int_o^\infty \left(v^3\right) F v^2 dv = \left(\frac{nm}{2}\right)\left(\frac{2KT}{\pi m}\right)^{3/2}$$

DEFINITIONS OF PLASMA "TEMPERATURE"

$$T(AVG) = \frac{2}{3}\frac{\langle ED \rangle}{\langle ND \rangle} \qquad T(RMS) = \frac{1}{2}\frac{\langle EF \rangle}{\langle NF \rangle}$$

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TWO MAXWELLIAN APPROXIMATION

TWO MAXWELLIAN DISTRIBUTION FUNCTION

$$F_2(v) = \left(\frac{m}{2\pi}\right)^{3/2} \left[\frac{n_1}{(KT_1)^{3/2}} e^{\left(\frac{-mv^2}{2KT_1}\right)} + \frac{n_2}{(KT_2)^{3/2}} e^{\left(\frac{-mv^2}{2KT_2}\right)} \right]$$

TWO MAXWELLIAN PLASMA MOMENTS

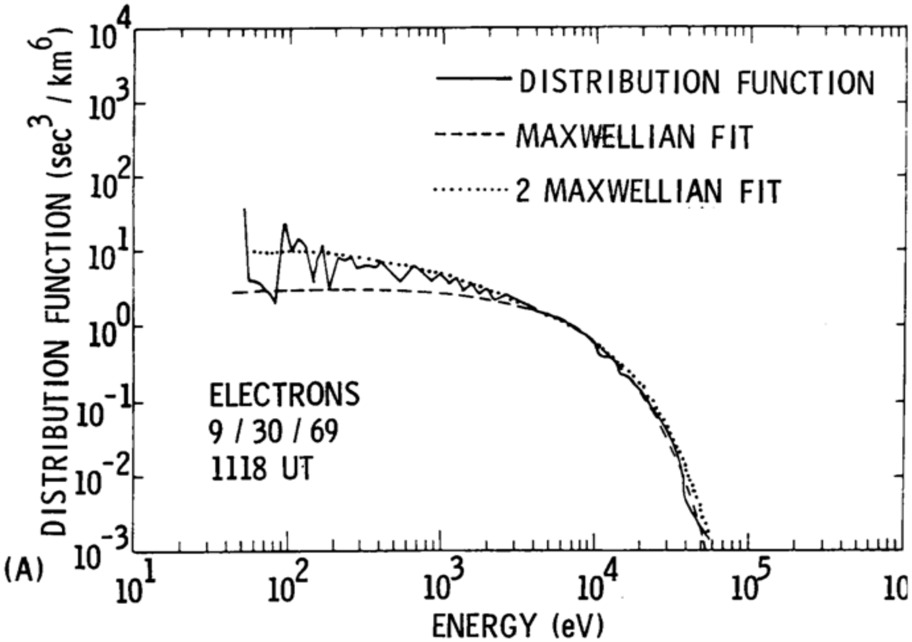
NUMBER DENSITY: $M_1 = n_1 + n_2$

NUMBER FLUX: $M_2 = \frac{n_1}{2\pi}\left(\frac{2KT_1}{\pi m}\right)^{1/2} + \frac{n_2}{2\pi}\left(\frac{2KT_2}{\pi m}\right)^{1/2}$

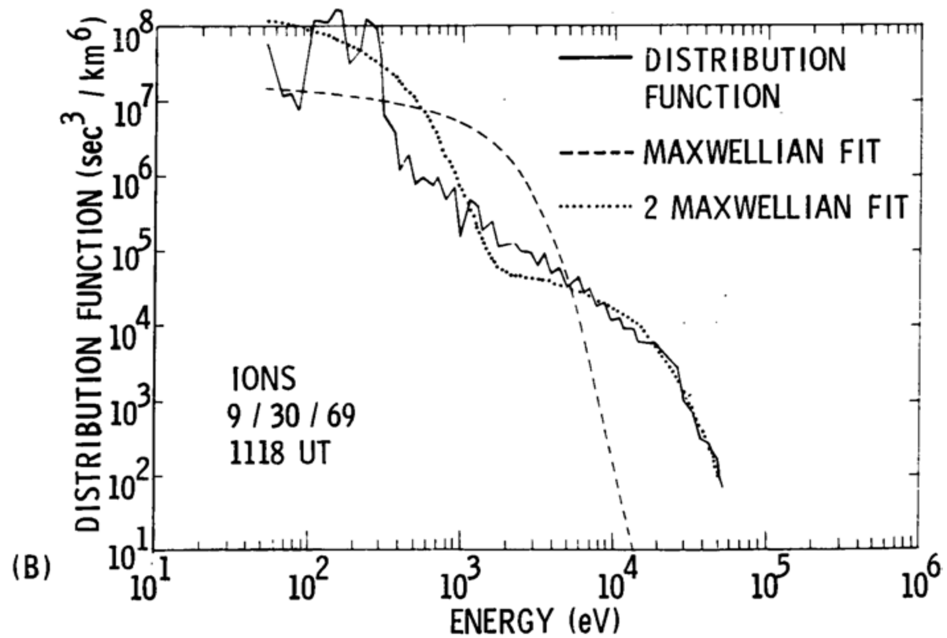
ENERGY DENSITY: $M_3 = \frac{3}{2} n_1 KT_1 + \frac{3}{2} n_2 KT_2$

ENERGY FLUX: $M_4 = \frac{n_1 m}{2\pi}\left(\frac{2KT_1}{\pi m}\right)^{3/2} + \frac{n_2 m}{2\pi}\left(\frac{2KT_2}{\pi m}\right)^{3/2}$

ELECTRON AND PROTON GEOSYNCHRONOUS PLASMA DISTRIBUTION FUNCTIONS



ELECTRON DISTRIBUTION



PROTON DISTRIBUTION

ATS-5 AND ATS-6 STATISTICS

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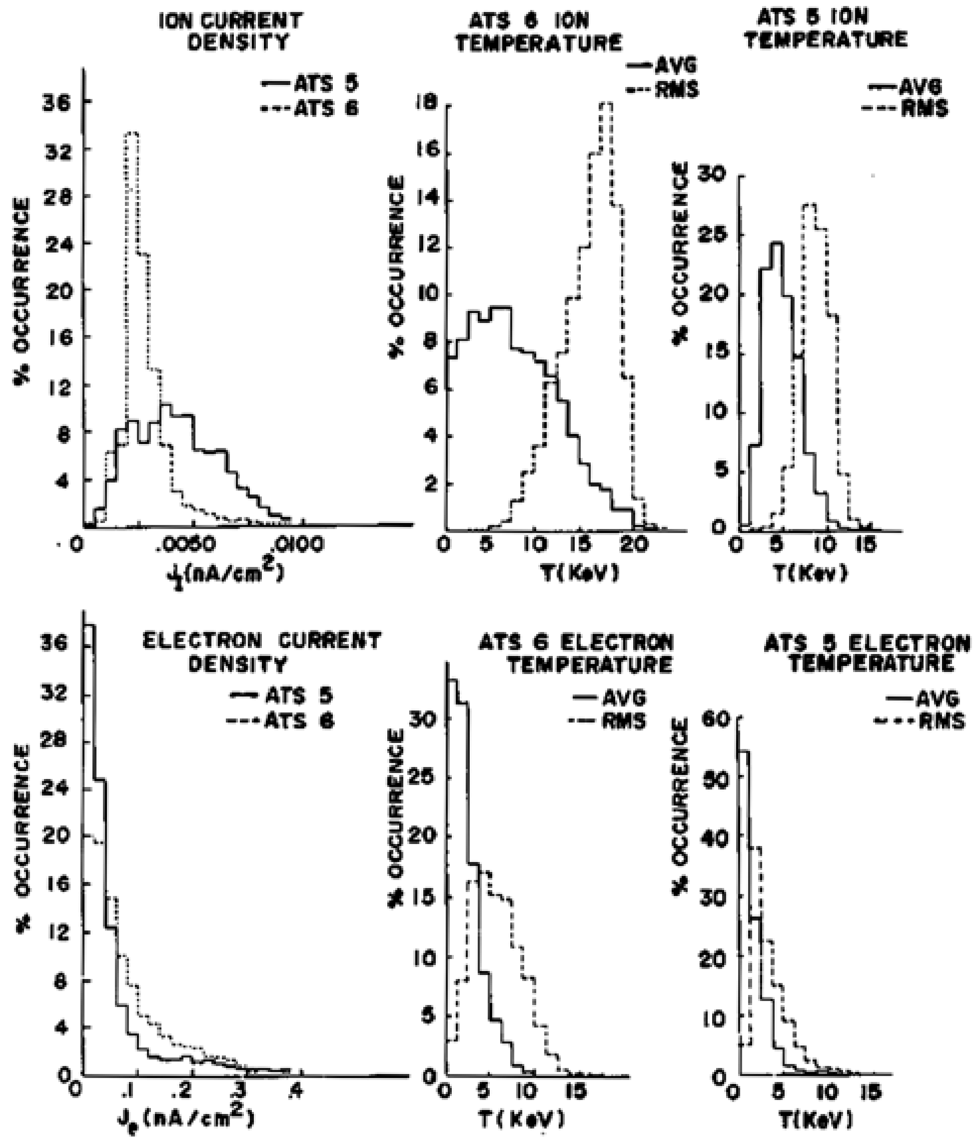

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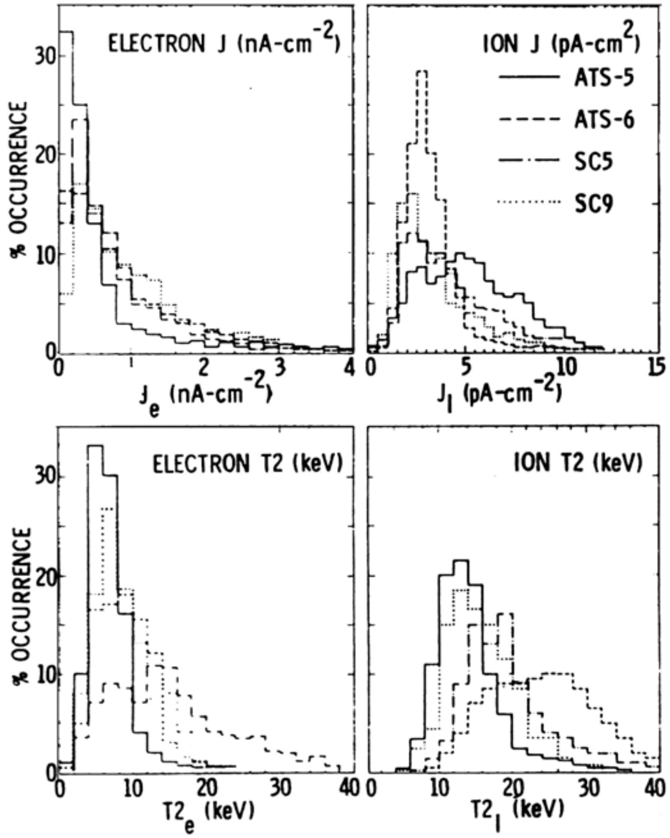
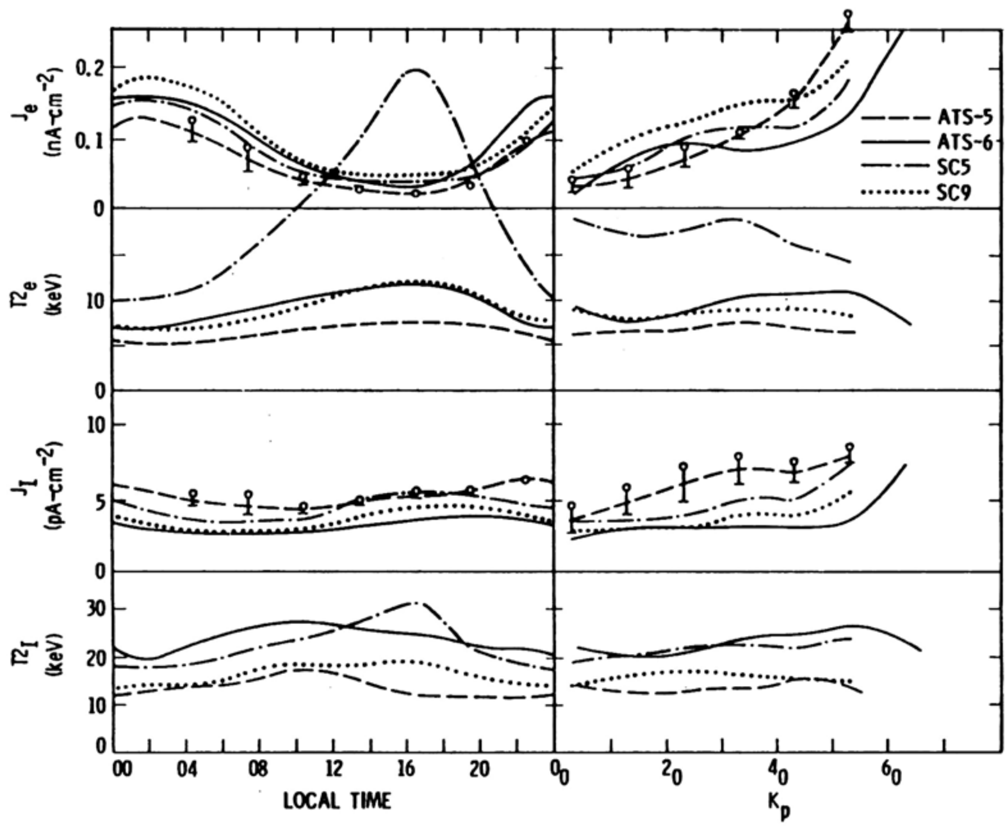
THE GEOSYNCHRONOUS PLASMA

STATISTICAL DISTRIBUTIONS OF KEY GEOSYNCHRONOUS PARAMETERS



LOCAL TIME/Kp VARIATIONS FOR KEY GEOSYNCHRONOUS PLASMA PARAMETERS



ANALYTICAL MODELING

- Key plasma parameters can be fit in terms of local time, geomagnetic activity (Kp/ap, L-shell, time-after-injection, etc.)
- Analytic models provide simple, compact representation of primary plasma variations

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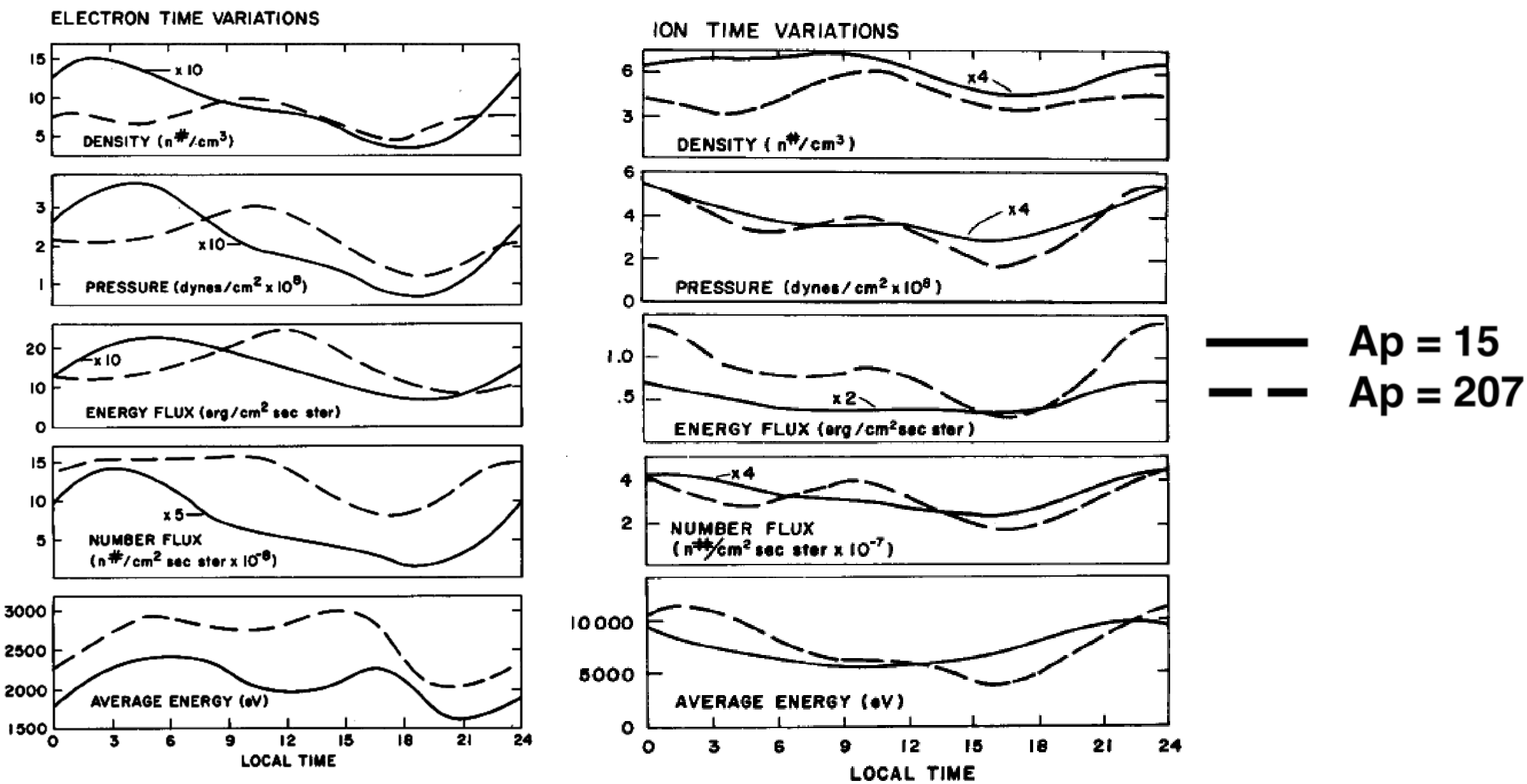
ANALYTIC MODEL OF THE GEOSYNCHRONOUS ORBIT



$$M_i\left(A_p, LT\right) = \left(a + bA_p\right)\left\{c + d\cos\left[2\pi\left(LT - e\right)/24\right] + f\cos\left[4\pi\left(LT - g\right)/24\right]\right\}$$

MODELED VS OBSERVED PLASMA PARAMETERS

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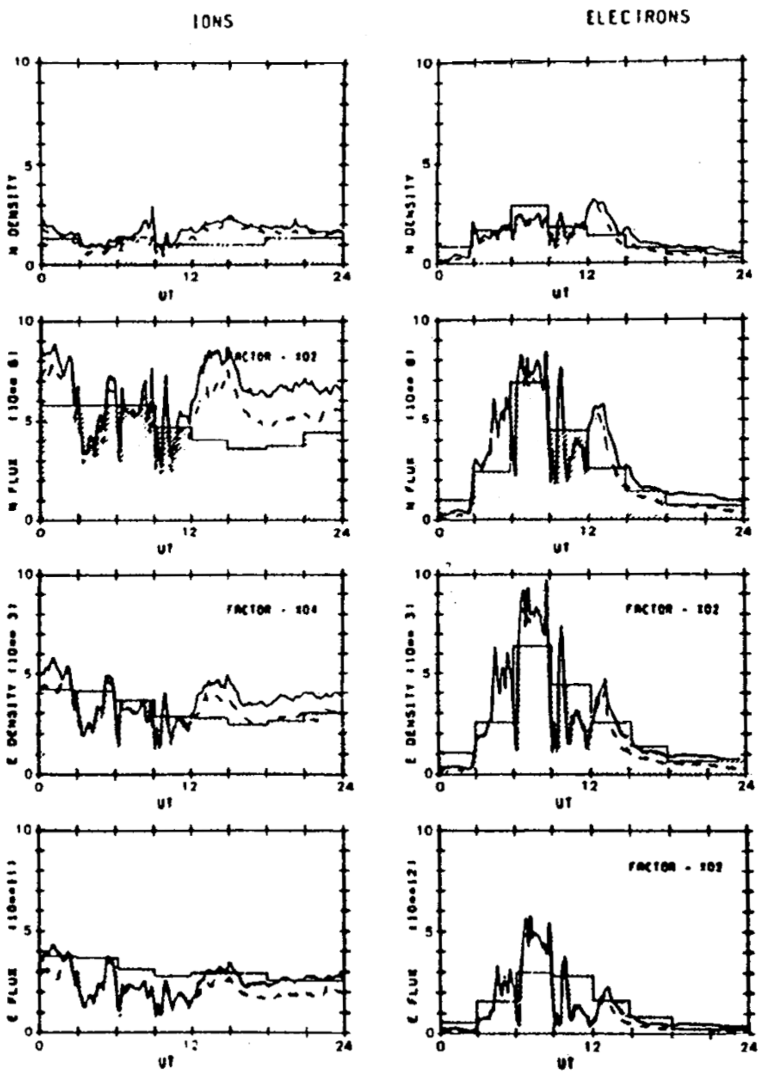

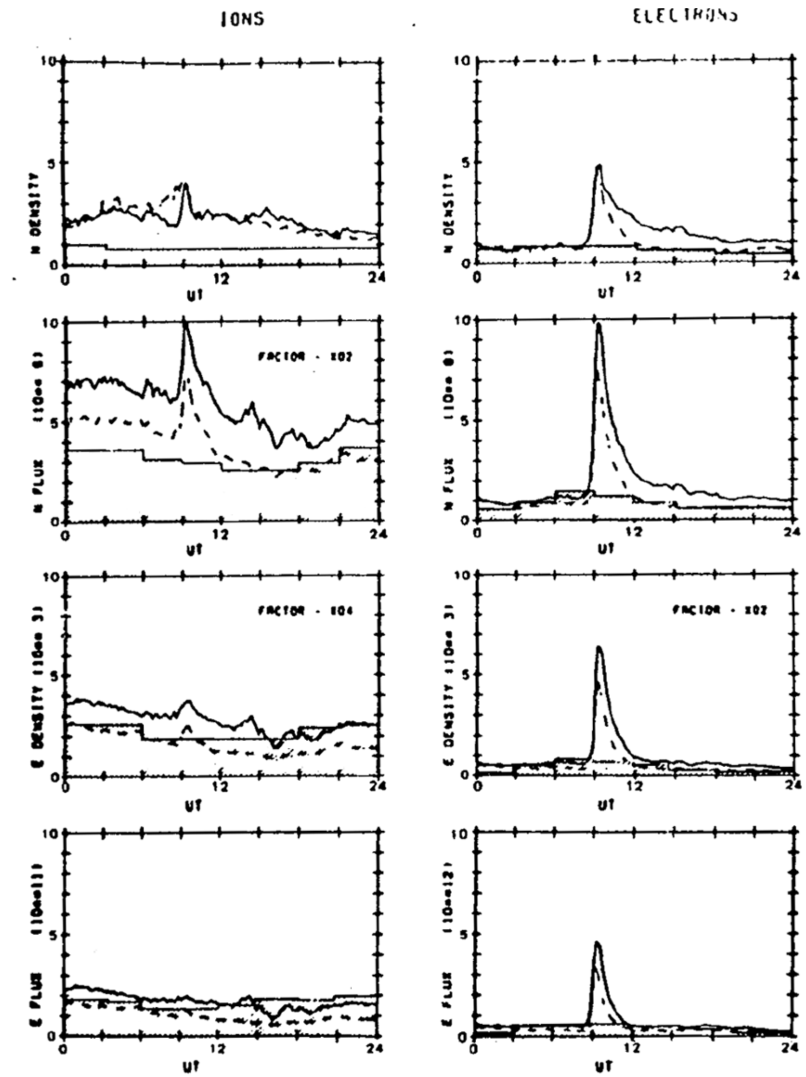

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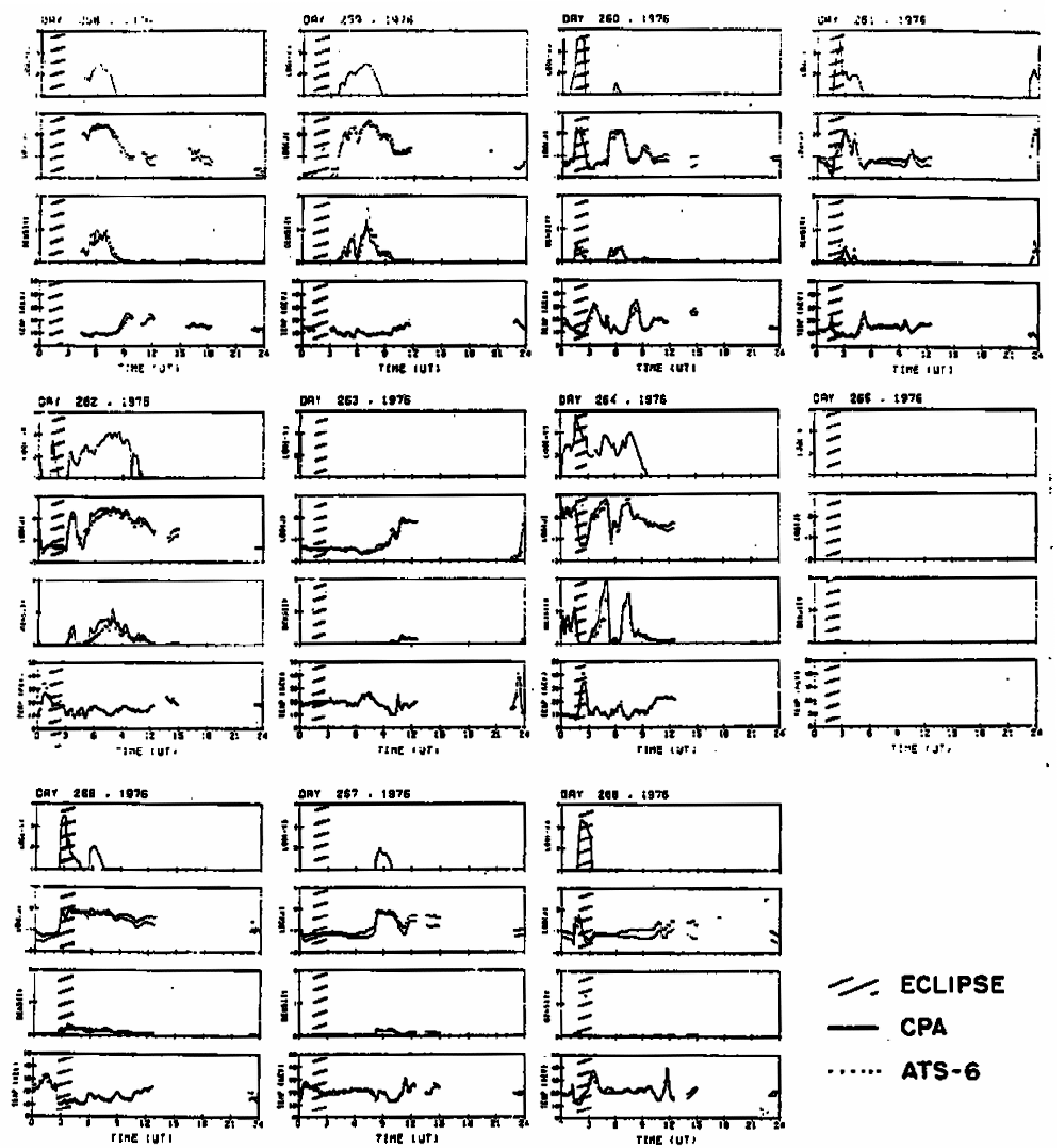
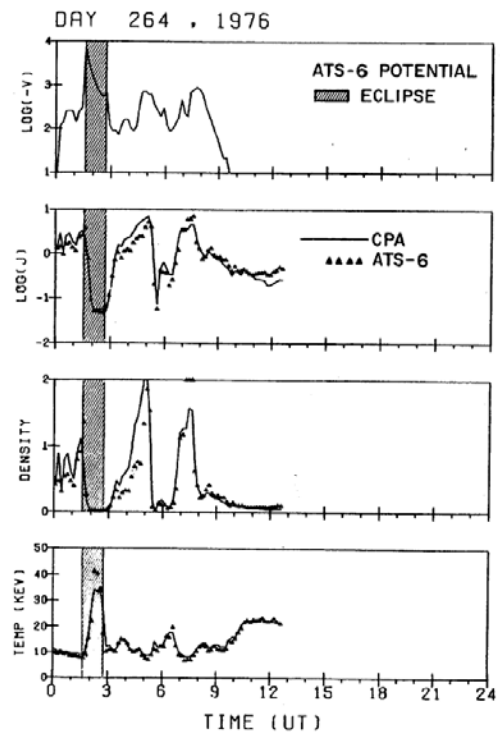
30-95 KEV ELECTRON DATA FOR ATS-6 AND LANL CPA 1976-059A FLY-BY





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POTENTIAL FUTURE ACTIVITIES

- Complete development of initial "Time-After-Injection" model
- Complete investigation of "Adiabatic" relationships between parameters
- Make original data more readily available--currently exists on 7-track tapes, detailed catalogs, microfiche, spectrograms, data atlases

SUBSTORM CURRENT DENSITY VARIATIONS

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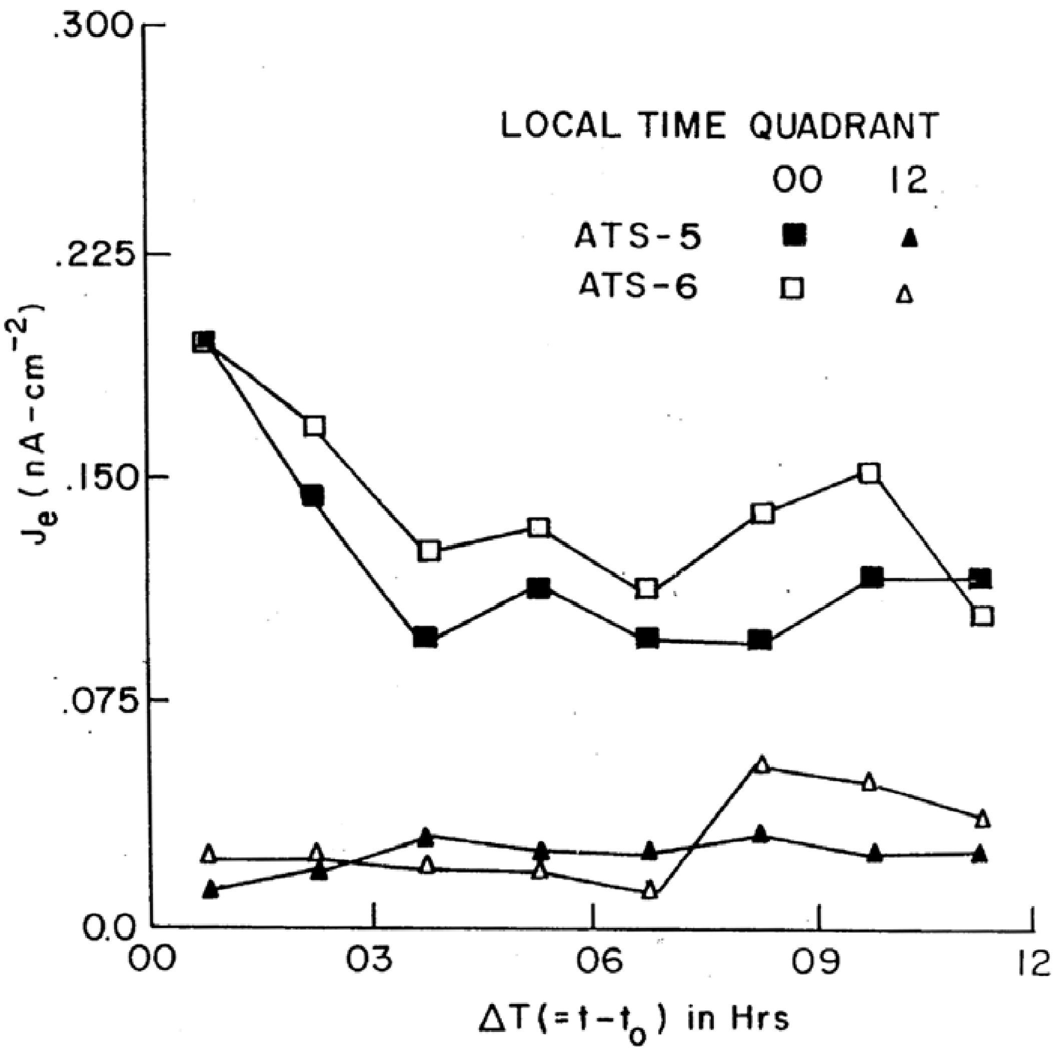

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ADIABATIC VARIATIONS IN ELECTRON PLASMA POPULATIONS